Current Issues in Emerging eLearning

Volume 6 | Issue 1 Article 6

2-27-2020

# Meaningful Engagement via Robotic Telepresence: An Exploratory Case Study

Tommy Lister
*Michigan State University*, listerth@msu.edu

# MEANINGFUL ENGAGEMENT VIA ROBOTIC TELEPRESENCE: AN EXPLORATORY CASE STUDY

Tommy Lister (*Michigan State University*)

Technology has created powerful advancements in education in support of students with a wide array of learning needs. Innovations for inclusive education have become increasingly emphasized over the past thirty years (Morningstar, Shogren, Lee, & Born, 2015; Sheehy & Green, 2011). Inclusive educational approaches have included great advancements in areas including Assistive technology (AT) and Universal Design for Learning (UDL) and are gaining emphasis as strategies to shape physical design and learning design attributes of schools (Edyburn, 2010; Waitoller and Thorius, 2016). Indeed, the influence AT has pushed educators to adopt practices and methodologies that support users reactively while the influence of UDL has pushed users to adopt supportive practices and methods, proactively to create richer, more robust learning experiences for all (Edyburn, 2010). Effectively deployed, inclusive educational design is providing all students greater opportunities for independence and academic success, regardless of their individual needs or circumstances (Morningstar et al., 2015).

Numerous researchers are also examining how inclusive educational design efforts may take a more central role in bridging gaps to create more holistic educational experience through social engagement (Sheehy and Green, 2011; Ahumada-Newhart and Olson, 2019). The desire to maintain a semblance of normalcy and a connection with peers is a critical concern for all children regardless of health and wellness (Liu, Inkpen, and Pratt, 2015; Newhart, Warschauer, and Sender, 2016). A sense of normalcy and engagement connects profoundly with rates of academic retention, levels of motivation, and even the depth of learners' sense of belonging (Ahumada-Newhart and Olson, 2019). Collaboration and a shared experience are important aspects of learning (Weiss, Whiteley, Treviranus, and Fels, 2001). Stronger academic outcomes have been linked to educational experiences that support a sense of normalcy and collaboration (Newhart and Olson, 2017) (Lui et Al, 2015). In their work on Self Determination Theory (SDT), Ryan and Deci proposed that competence, autonomy, and relatedness must be secured on an ongoing basis for learners to experience a sense of "integrity and well-being" (Ryan and Deci, 2000). Greater student autonomy has been linked to greater intrinsic motivation, curiosity, and even desire for challenge (Ryan and Deci, 2000). Conversely, a lack of autonomy and connectedness can result in a decline of initiative and responsibility taking as well as psychological distress (Ryan and Deci, 2000). Simply put, educational outcomes and social engagement are enhanced when students are able to engage fully and share in the learning experience with others.

However, despite the desire to foster normalcy and a shared experience, addressing learners' physical health issues often takes precedence. Students who suffer from long-term illness often endure forced isolation from their peers. The burden of illness often compounds with a loss in peer engagement, which loss sometimes make health conditions even worse (Liu et al., 2015). This serious problem has led researchers to creative innovations involving the use of robotic telepresence (RT) as a potential educational solution (Kristofferson et al., 2013; Newhart and Olson, 2017; Ahumada-Newhart and Olson, 2019; Sheehy and Green, 2011; Weiss et al., 2001). RT has gone through significant advances for a variety of uses ranging from basic video conferencing to spacecraft implementations; recent applications show promise for individual control in classroom contexts (Desai, Tsui, Yanco, and Uhlik, 2011; Tanaka, Takahashi, Matsuzoe, Tazawa, and Morita, 2014; Tsui, Desai, Yanco, and Uhlik, 2011). RT can be defined as remotely controlled autonomous movement enhanced with multi-way video and audio capabilities (Kristofferson et al., 2013; Tsui et al., 2011). Simply put, RT provides the ability for a remote access participant to see and be seen, to hear and be heard, and to move a self-representing mechanism freely in a given space in order to foster engagement and social interactions (Kristoffersson, Coradeschiz, and Loutfi, 2013; Newhart and Olson, 2017). As RT has continued to gain traction as an interaction and engagement solution, researchers continue to examine the impact RT has on social presence and academic performance (Nakanishi, H., Murakami, Y., and Kato, K., 2009; Ahumada-Newhart and Olson, 2019).

Educational applications of RT have expanded in recent years with an emphasis on social engagement and academic inclusion. *Virtual inclusion* is a term used to describe circumstances in which remote students can engage fully as if physically present; the concept of virtual inclusion has become central to conversations regarding remote learners' engagement with teachers and peers over a variety of school contexts (Ahumada-Newhart and Olson, 2019; Kristofferson et al., 2013; Newhart et al., 2016). Although conceptually possible to have teachers connect remotely to geophysical students, most studies explore situations in which remote students connect with teachers and peer students located in a traditional school setting (Ahumada-Newhart and Olson, 2019; Lui et Al, 2015; Newhart et al., 2016; Newhart and Olson, 2017; Sheehy and Green, 2011). While there may be numerous practical reasons for this reality including the inconceivable hurdles associated with classroom management by robot, it is also true that schools have ready contingencies for teachers who miss teaching while there aren't such solutions for students who must miss learning.

This case study explores one instance of the relatively new context of RT solutions for including remote learners in the activities taking place in classroom environments. The study adds to the growing collection of data regarding unique contexts and recommendations. The research questions can be summarized as:

A. How does robotic telepresence influence virtual inclusion and normalcy?
B. How does the use of robotic telepresence influence remote learners' perception of their autonomy?
C. Can robotic telepresence improve remote learners' perception of their socio-emotional engagement?

## METHOD

This case study centers on a student whose long-term illness made her physically unable to attend school. The school district initially provisioned her with remote tutoring and some video conferencing as a solution to traditional classroom based instruction. However, after numerous complications and subpar experiences, the school district contacted our educational research team at Michigan State University (MSU) given our established work in the field of robotic telepresence in educational settings. Our team has years of documented research and experimentation using RT in a variety of educational contexts. Additionally, our faculty and students have years of experience with similar devices for a myriad of uses in higher education contexts. My own prior experiences as a K-5 classroom teacher and now as educational researcher added a unique perspective into not only what daily rhythms are like for K-5 classrooms but also for what the teacher was apt to feel with the added pressures. As a result, our multifaceted experiences provided a unique foundation in support of classroom contexts as well as teacher and student trainings with actual RT devices from those who had used these devices for years. Our collaborations empowered the teacher and school administrators in the acquisition of RT as a potential improvement to this situation.

The exploratory nature of this case study research placed project participants in a unique position to discover, interpret, and gain greater awareness of organic experiences and personal perspectives in a genuine context (Yin, 2014).

## PARTICIPANTS

The implementation project behind this case study took place in a Midwestern suburban elementary school in a predominantly White, middle-class district of 48% female to 52% male students with approximately 16% of the students receiving free or reduced lunch. This study examines the educational experiences of an 11-year-old girl, Cortana (pseudonym), as she transitioned from independent study enhanced through videoconferencing to full class participation via robotic telepresence. Cortana was able to attend a mainstream classroom through her third grade year. However, during her fourth- and fifth-grade years she was medically required to limit her exposure. Fortunately, Cortana retained the same teacher, Mrs. Halsey (pseudonym), and largely the same peer student group for both her fourth and fifth grade school years. Her initial IEP (Individualized Education Plan) provisioned occasional home tutoring and occasional opportunities to connect to her classmates via videoconferencing while her family transported homework assignments to and from school each day. However, the level of interaction supported by these videoconference sessions was limited to occasional weekly meetings of 20-30 minutes at a time. Additionally, due to limited technology resources, the teacher often defaulted to video conferencing with Cortana via a personal smartphone device and physically moving around to change the camera perspective in the class. These complications and limited resourcing severely impacted the overall effectiveness of the strategy. The result was that the daily sessions rapidly devolved into a once weekly 30-minute session during which Cortana could barely see or hear her classmates, teacher, or the lesson. The mounds of classwork delivered each day after school by her family members was overwhelming and, without guidance or explanation, the work was often difficult for Cortana to decipher and nearly impossible for her to keep up with.

## PROCEDURE

Three distinct groups (subject student, teacher, and peer students in groups) were identified for interviews for the purpose investigating the influence of RT on student perceptions of virtual inclusion, normalcy, autonomy, and their socio-emotional engagement in the class context (see Appendix B: Interview Questions -- Pre and Post). Each peer student group comprised 5-8 students. Each interview lasted roughly thirty minutes with a semi-structured questioning format for each group. The research team coordinated to send two of its members, one faculty member and one doctoral student, to conduct private interviews with each of the groups. Interviewees were also provided dedicated pauses for reflection between questions and answers. Interviewees were also allowed to provide additional comments or clarifications both during and after the questioning. The teacher

provided additional written reflections after the interview phase for added context and depth and insights.

## MATERIALS

The implementation project discussed in this case study utilized a Beam Pro robotic telepresence device. The Beam Pro robot is controlled by a simple web based software using standard keyboard controls. The software enables the user to move the remote device in 360 degrees, to adjust speed controls for slower or faster movement, to adjust camera angles and zoom, and to adjust both microphone and speaker volumes.

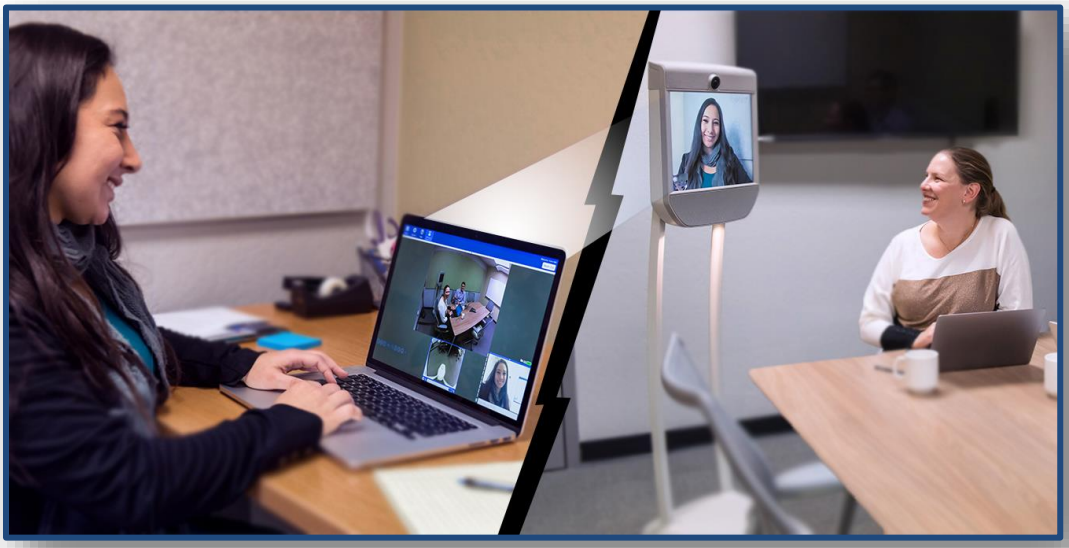

Photo used with permission from SuitableTech.com.
Original source: *https://suitabletech.com/press-kit*

The Beam robot also has built in software and audio filters to reduce ambient noise. It has dual cameras to provide the user the ability to *zoom in* and *zoom out* in order to gain perspective in spatial reasoning and piloting. It does not have any provisions that would enable hand-type functions remotely, which is currently a common limitation for this type of robotic solution (Leithinger, Follmer, Olwal, and Ishii, 2014).)

IRB permission was obtained through the university process and the teacher (Mrs. Halsey) elicited permissions parent consent for each of the students interviewed.

## ANALYSIS

As an isolated intervention, this study also utilized triangulation, comparison, and respondent validation to reduce validity threats (Maxwell, 2013). The interview groups were isolated and conducted privately. The peer interview groups were

conducted separately and had some variation in participants. This allowed the researchers to identify trends and alternative perspectives to experiences and events from multiple vantage points. Furthermore, as the principal interviewees were child subjects, it was prudent to approach the interviews with multiple *science-based* approaches to interviewing children (Saywitz et al., 2017). The interviews were semi-structured in nature, but included rapport development, age-appropriate language and concept descriptions, generalized questions to avoid leading language and protect against suggestibility, as well as an authority free interview environment (Saywitz et al., 2017). The peer group interviews were conducted in multiple groups with rotating respondent order to limit groupthink and allow greater opportunity to isolate themes. Additionally, to reduce researcher bias and reactivity, the initial interviews were conducted and recorded by one researcher while the second round of interviews were conducted blind by a second researcher (Maxwell, 2013).

Each interview was digitally recorded (audio) and then transcribed. After the initial interviews, the recorded audio was again reviewed for enhanced notation of details. Then the transcriptions were reviewed, coded, and analyzed to isolate and interpret themes. The review compared findings between both the notes taken and the coded results from the transcriptions. Similarities between each of these elements were noted and compared for each research group in order to isolate patterns and themes.

## RESULTS

Analysis of all three groups (student, teacher, and peers focus groups) yielded similar themes with varying degrees of emphasis. These themes were coded and organized into four categories including a) improvements for relational normalcy and autonomy, b) personal agency in learning, c) rapid acceptance and normalization of the robotic device, and d) prescription for future use. Not surprisingly, the most positive themes were voiced by the subject participant herself (Weiss et al., 2001).

### *GAINS TO NORMALCY AND AUTONOMY*

Cortana was explicit: "I feel like I am there." Easily the most prominent theme was how RT improved Cortana's feelings of connection and a perceived social normalcy. For Cortana, her prior isolation and severe lack of social engagement had been disheartening. The previous efforts to connect via videoconference resulted in frustration for Cortana and were in general an underwhelming experience. "I wasn't really there. I still feel like I was at home... Like I was sort of part of the class but not really because I … like I wasn't there … because I couldn't do as much as they were doing."

The use of RT brought about a level consistency and regularity that dramatically improved Cortana's ability to engage with her peers and with her teacher. Her statements made during the interviews revealed the perception that

Cortana could freely engage others both in location and movement. The space that the RT occupied was her space. She could adjust her location and visual perspective. She could engage in whole class conversations or adjust her volume down appropriately for one-to-one interactions. This dramatic shift in control provided Cortana with a strong sense of autonomy and a participatory normalcy in her classroom. She perceived herself to be once again an active member of the classroom and not just an occasional guest visitor.

Her personal control of robotic movement was related to higher perceived social presence and an identity both in and beyond the classroom. She was also able to focus in on individual peers and ask them clarifying questions, thus enhancing her peer-to-peer collaboration in learning; conversely, when using conventional video conferencing technology to join the class, she was limit to always addressing the entire class at once. The ability to initiate and participate in one-to-one and small group discussions gave Cortana the chance to engage her peers both academically and socially; she could ask her friends for a clarification on an assignment and engage in social conversations that often occurred within and between lessons. Cortana was also able to venture beyond the classroom and engage in extra curricular contexts including the school STEAM program, art, and music. Furthermore, she was able to participate in a fifth-grade service-learning program in which fifth graders are partnered with second graders in a mentoring program. She was able to mentor her own second grader. Cortana cited the second graders' initial shock, noting this reaction gave way to subsequent rise in Cortana's popularity with the mentee:

> She was surprised and she was like, oh, that's cool. I know you're still my partner, but you're just in a different form. That's really cool. And then all the other buddies were like "Oh… that's cool. " [They] were all thinking positive things about it.

RT enabled Cortana not only to engage in irreplaceable life experience, but it also empowered her as one who could contribute to others' successes, rather than operating only as a recipient of assistance. She felt like and indeed was again in a position to help others. In addition to educational achievement, school provides social and communication engagement helpful in building autonomy. RT made it possible for Cortana to venture outside of the classroom and it gave her the ability to engage more fully in the experiences of student life. She was again part of the greater school community.

### *PERSONAL AGENCY IN LEARNING*

Comparing her experiences, Cortana cited multiple times how frustrating and limiting basic video conferencing was as compared to RT. Her ability to connect and to stay engaged with her class was extremely difficult and often frustrating.

> If they wanted me to look at a book or something or a see picture it was super hard because it was blurry through the screen. And [Mrs. Halsey] had to move me around holding her phone and I couldn't see everyone and that was why she had to move me around so much.

Beyond the obvious lack of control and the subpar video graphic experience associated with video conference enabled classroom participation, Cortana also had felt that she was a burden to her teacher and to her classmates, given the fact that they had had to facilitate her movement. This undo pressure often became so unbearable that she would rather not connect than become a burden to her teacher or classmates. However, with the robotic telepresence system, Cortana gained newfound control over her perspectives of the classroom, allowing her to make adjustments and adapt to the lesson dynamics easily. The RT controls allowed her to pivot and focus her camera anywhere in the room. "I can zoom in as much as I need to, to see what I need." Both Mrs. Halsey and Cortana cited a dramatic improvement in Cortana's ability to participate in almost every classroom-learning context; the RT system provided her freedom of movement and opportunities for holistic engagement. RT opened the opportunity for Cortana to participate daily. "I was there when they were there …." Multiple times Cortana cited how pleasantly surprised she was to be able to participate so fully. "I was surprised actually…. I didn't think I was going to be able to do all of that."

Any limitations to Cortana's agency within her new relationship to the remote classroom were associated with the robotic device's lack of advanced actions including the ability to engage with robotic hands or traverse in all terrain environments. Multiple times during interviews, both Cortana and members of the student focused groups cited that it would have been nice to have Cortana interact by blanking her telepresence robot to hold, lift or manipulated during class activities. "I [can] guide them [my classmates] through it, but I can't really let it [the robot] help them do it." Although most developers of RT technologies have focused on the development of reliable audio, video, and basic movement and have delivered products that offer these features, telepresence robot units on the market today commonly do not provide the remote user functions that replicate human, dynamic motions (Desai et al., 2011).[1]

***RAPID ACCEPTANCE OF ROBOTIC NORMALCY (ANTHROPOMORPHISM)***

[1] Trends in the field of robotics suggest we will soon see significant advances in the implementation of human dynamic motion functionality. Magrini, Flacco and DeLuca (p. 2298) report the following in their introduction to a 2015 IEEE *international conference on robotics and automation (ICRA)*paper titled "Control of generalized contact motion and force in physical human-robot interaction":

> In the robotics community at large, there is great excitement about the recent possibility of realizing safe physical collaboration between human users and a new industrial generation of lightweight, compliant and friendly robots.

Members of all three participant groups identified general, rapid acceptance of the anthropomorphic characteristics of the RT device operating on Cortana's behalf and under her remote control within the classroom community. Both Mrs. Halsey and the peer groups noted what seemed like instantaneous acceptance of the RT in the classroom, a phenomenon cited in the literature (Newhart et al., 2016). "Of course, after about two days, you know…. it's like, Oh yeah, here's [Cortana]" and how students would call out "[Cortana] is here! [Cortana] is here!" whenever the RT device chimed with her login. Mrs. Halsey and the students both talked about the initial fascination with the RT device in the room, but how with in a manner of days it became the new normal; the robot represented Cortana and was assigned what would be her place in the classroom. Her peer students and teacher both specifically named how the Beam Pro was synonymous with Cortana. "Oh yeah, here's [Cortana]. She just beamed in and they get out of her way, you know, when she's doing things and she tells him to be quiet when they're too loud… that's pretty funny." She once again occupied her space in the classroom. This type of response embodied a growth in an awareness and empathy for others, a result similarly found in other telepresence research (Weiss et al., 2001). Similarly, the anthropomorphic identification that Cortana's class experienced has been a similar theme in RT research (Newhart et al., 2016). The robotic device *was* Cortana when she was connected.

While Cortana enjoyed rapid acceptance of her remote telepresence among classmates and her teacher, this acceptance rate contrasts with reactions among less familiar adults and some peers around the school. Cortana described the situation as follows:

> Most of the fifth graders are like 'that's [Cortana] we know what's going on and she has a robot, and that's how she goes to school.' It's just normal. But the third graders are kind of like 'Hmm, what's that?' At first I was like 'Okay, you're staring at me. It's different for you guys and it's different for me.' But after they did it a couple times I'm like 'Stop. Please.'

Cortana attributed this stark difference in acceptance levels with the lack of contact and interaction among the fifth graders and third graders. The two grades are located at opposite ends of the school and almost never cross paths. Other studies also note this trend relating lack of novelty to acceptance and limited exposure to a lack of acceptance (Newhardt et al., 2016). Mrs. Halsey noted a similar situation involving substitute teachers or remote school staff: "So usually if there's a guest teacher, I think what happens is Cortana beams in and when she sees there's a sub she beams out." Although Cortana's RT became normalized relatively quickly for the people within the school environment who came in contact with Cortana through her remote use of the Beam Pro, achieving RT

normalcy did require some time and sustained interaction. Apparently in the case of one-day substitutes, Cortana often didn't see the value add.

### *RECOMMENDATION FOR FUTURE USES*

Each interview conducted for this case study included an emphasis on how this type of solution may yield positive results for other people who may have physical or health concerns in the future. The primary line of inquiry during interviews regarded potential future academic use cases whereby more students could connect by robot. Indeed, all three groups (Cortana, Mrs. Halsey, and the peer students) saw no reason why such a provision would not be immediately available to schools, albeit with consideration needed to support adding such sophisticated technological infrastructure.

In addition to the obvious infrastructure requirements including sufficient classroom space and stable Internet connections, Mrs. Halsey cited the dramatic increase in forward planning that was required to teach to multiple modalities. The intentionality required in arranging classroom lessons, provisioning remote supplies, and even furniture to accommodate the robotic movement proved to be significant. Responsive teaching practices, wherein the teacher is adapting to student learning needs, can be quite difficult to support, as Ms. Halsey acknowledged:

> We try to send materials home so that she can actually do it when it gets there…. A lot of time she had stuff, but [if something came up] it was like, 'Oops, well let me take a picture of this…' So that's, that part's a little bit tricky.

## DISCUSSION

Returning to the initial conversation on inclusive education, this case study illuminates several key aspects of what it means to be a participant in learning. Despite the obvious infrastructure needs associated, there are complexities in both learning and teaching in alternative modalities. Students rely on couriers to receive classroom provisions. Teachers must plan proactively and prepare and resource to multiple sites as well as communicate between sites. Teaching in multiple modalities adds complexity, and especially so when teaching in real time. But despite the additional accommodations, all parties involved found the experience to be enriching and important. Both the teacher and the students saw RT as an obvious solution to a great many possible obstacles; from the teacher's perspective the learning gains resulted in significant hope for diverse use cases.

The participants in this study all quickly highlighted how the use of robotic telepresence dramatically improved Cortana's ability to learn with her peers, but they also highlighted how this fundamentally changed how she engaged with others. Humorously, one of Cortana's peer students reflected on how he would give her the ability to engage with them in other, broader experiences, stating: "I'd give it like legs and arms so I could go outside and do activities with us… [Because] we have to run the mile sometimes so then [Cortana] can run the mile [too]." This desire to have her join in on the grander experiences provides a powerful illustration of co-learners' investment in Cortana's success. Although, perhaps upon further reflection this student would realize that a robotic mile-time is rather superfluous, the spirit of the statement reflects a deeper desire for connection that resonated with all of Cortana's peers. Their desire to be connected with Cortana matched her own deep desire for connection with them.

Educators and researchers alike may often gravitate toward the process of teaching or the intersection between pedagogy and curriculum, but the nature of successful learning is often much deeper and much more complex. The representative data collected through this case study illustrates promising but complex characteristics of RT in a classroom context. Undoubtedly RT technology created experiences in support of both academic and social development for a remote student, experiences that were not otherwise possible through video conferencing. This case study seems to highlight the importance of autonomy, normalcy, and connectedness in learning. The gains made by Cortana in each of these areas were noted by each of the groups, but perhaps it was the gains to all three of these areas as a collective that made the greatest experiential difference. The remote student was able to utilize RT to represent herself, to leverage control in learning, and to connect with others in context.

## LIMITATIONS

This exploratory case study focuses on the experiences of one RT student, her teacher, and classmates. It was designed specifically to investigate phenomenon in a given RT situation rather than to assign globalizing meanings to case study outcomes. Inherent in this approach is the researchers' bias as well as the participants' own particularities. Although we controlled for in these characteristics, there is also a natural risk of *groupthink* that can be associated with group interviews. Finally, interviewing children can also provide some limitations in interpretation related to external influencers such as the assumption of perspectives held by the classroom teacher or other related adults. Although this too was controlled for, it must be noted as a known limitation inherent in research of this type.

## CONCLUSIONS

As is the nature of qualitative work, these results are specifically tied to the experiences of the participants and this case study. The insights from lived experiences explored in this case study support the premise that RT provided a dramatic improvement over video conferencing and over Cortana's independent, remote (at-home) study. Cortana experienced significant gains related to autonomy, social engagement, and agency in learning. The potential and promise of robotic telepresence is remarkably positive. For everyone involved, this RT deployment was a critical success and a huge improvement upon the prior remote study strategies involving video conferencing augmentation. The marked improvements in both learning and social engagement support the idea that the increased autonomy enabled by the RT was powerful. This research supports numerous similar studies that have found RT may provide an important solution for supporting children with illness or disability. RT provides unique possibilities for fostering inclusive education. Robotic telepresence may operate to the betterment of all learners, robotically connected or otherwise.

## IMPLICATIONS FOR FURTHER STUDY

Given the findings in this case study and the rapidly expanding research and design efforts in robotics, replication and extension of this research will be critical in determining future implications and applications for supporting robotic assisted learning in broader educational contexts. As RT technologies progress so too will the range of RT opportunities in educational contexts. It is reasonable, therefore, to assume that advancements in RT will help to steer future research and broader educational uses as it affords more creative solutions to unique contexts.

## REFERENCES


Ahumada-Newhart, V., & Olson, J. S. (2019). Going to School on a Robot. ACM Transactions on Computer-Human Interaction, 26(4), 1-28. doi:10.1145/3325210

Desai, M., Tsui, K. M., Yanco, H. A., & Uhlik, C. (2011). Essential features of telepresence robots. 2011 IEEE Conference on Technologies for Practical Robot Applications. doi:10.1109/tepra.2011.5753474

Edyburn, D. L. (2010). Would You Recognize Universal Design for Learning if You Saw it? Ten Propositions for New Directions for the Second Decade of UDL. *Learning Disability Quarterly,33*(1), 33-41. doi:10.1177/073194871003300103

Hooker, Mike. 2011. "Robot Goes To Class for Student with Dangerous Allergies." CBS Denver. "Instructions for the Home Teacher." n.d. New Haven, CT.

Kristoffersson, A., Coradeschi, S., & Loutfi, A. (2013). A Review of Mobile Robotic Telepresence. Advances in Human-Computer Interaction, 2013, 1-17. doi:10.1155/2013/902316

Leithinger, D., Follmer, S., Olwal, A., & Ishii, H. (2014). Physical telepresence. Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology - UIST 14. doi:10.1145/2642918.2647377

Liu, L. S., Inkpen, K. M., & Pratt, W. (2015). "I'm Not Like My Friends". Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW 15. doi:10.1145/2675133.2675201

Magrini, E., Flacco, F., & De Luca, A. (2015, May). Control of generalized contact motion and force in physical human-robot interaction. In 2015 IEEE international conference on robotics and automation (ICRA) (pp. 2298-2304). IEEE.

Maxwell, J. A. (2013). Chapter 6. In Qualitative research design: An interactive approach (3rd ed.). Thousand Oaks, CA: Sage.

Morningstar, M. E., Shogren, K. A., Lee, H., & Born, K. (2015). Preliminary Lessons About Supporting Participation and Learning in Inclusive Classrooms. Research and Practice for Persons with Severe Disabilities, 40(3), 192-210. doi:10.1177/1540796915594158

Nakanishi, H., Murakami, Y., & Kato, K. (2009). Movable cameras enhance social telepresence in media spaces. *Proceedings of the 27th International Conference on Human Factors in Computing Systems - CHI 09*. doi:10.1145/1518701.1518771

Newhart, V. A., & Olson, J. S. (2017). My Student is a Robot. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI 17. doi:10.1145/3025453.3025809

Newhart, V., Warschauer, M., Sender, L. (2016). Virtual Inclusion via Telepresence Robots in the Classroom: An Exploratory Case Study. The International Journal of Technologies in Learning, 23(4).

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78. doi:10.1037//0003-066x.55.1.68

Sheehy, K. and Green, A. (2011). Beaming Children Where They Cannot Go: Telepresence Robots and Inclusive Education: An Exploratory Study. Ubiquitous Learning: An International Journal. 135-146.

Tanaka, F., Takahashi, T., Matsuzoe, S., Tazawa, N., & Morita, M. (2014). Telepresence robot helps children in communicating with teachers who speak a different language. Proceedings of the 2014 ACM/IEEE International Conference on Human-robot Interaction - HRI 14. doi:10.1145/2559636.2559654

Tsui, K. M., Desai, M., Yanco, H. A., & Uhlik, C. (2011). Exploring use cases for telepresence robots. Proceedings of the 6th International Conference on Human-robot Interaction - HRI 11. doi:10.1145/1957656.1957664

Waitoller, F. R., & Thorius, K. A. K. (2016). Cross-pollinating culturally sustaining pedagogy and universal design for learning: Toward an inclusive pedagogy that accounts for dis/ ability. Harvard Educational Review, 86(3), 366–389. doi: 10.17763/1943-5045-86.3.366

Weiss, P. L., Whiteley, C. P., Treviranus, J., & Fels, D. I. (2001). PEBBLES: A Personal Technology for Meeting Educational, Social and Emotional Needs of Hospitalised Children. Personal and Ubiquitous Computing, 5(3), 157-168. doi:10.1007/s007790170006

Yin, R. (2014). Designing case studies. In Case study research: Design and methods. (pp. 27-67). Thousand Oaks, CA: Sage

## APPENDIX A: INTERVIEW QUESTIONS -- PRE AND POST

### I. PRE-INTERVENTION QUESTION ORDER

A. RT student interview:

1. Can you tell me your name? And would you tell me your favorite book?
2. Do you like new technology?
3. How have you "come to class" via technology? (like FaceTime or a video conference)
    a What did you use?
    b What was good about that?
    c What wasn't so good about that?
    d What activities worked well?
    e What activities didn't work so well?
    f How is that different from being physically present?
    g How well could you see and hear?
4. (TP) Did you feel like you were really a part of class? If not, what was missing?
5. (TP) Did it seem like the people in the room kind of forgot about you?
6. Before this class, what did you know about "robotic telepresence" (coming to class by robot)?
    a How much have you experienced it so far?
    b What is it like?
    c What are you excited about?
    d What are you not so excited about?
    e Does this make you wonder about the future of school?

B. Teacher interview:

1. How would you describe your general attitude about technology in the classroom? Are you excited about it? Hesitant?
2. Has someone ever "come to class" via technology? (like FaceTime or a video conference)
    a What did they use?
    b What was good about that?
    c What wasn't so good about that?
    d What activities worked well?
    e What activities didn't work so well?
    f How is that different from being physically present?
    g Did it seem like she was really a part of class? If not, why?

## I. PRE-INTERVENTION QUESTION ORDER (continued)

3. Before this study, what did you know about "robotic telepresence" (coming to class by robot)?
    a How much have you experienced it so far?
    b What is it like?
    c What are you excited about?
    d What are you not so excited about?
    e Does this make you wonder about the future of school?

C. Student focus groups:

1. Can you tell me your names? And would you tell me your favorite books?
2. Do you like new technology?
3. Has someone ever "come to class" via technology? (like FaceTime or a video conference)
    a What did they use?
    b What was good about that?
    c What wasn't so good about that?
    d What activities worked well?
    e What activities didn't work so well?
    f How is that different from being physically present?
    g How well could you see and hear?
    h Did it seem like the people in the room kind of forgot about you?
    i Did you feel like you were really a part of class? If not, what was missing?
    j Did if feel like she was really a part of class? If not, what was missing
4. Before this class, what did you know about "robotic telepresence" (coming to class by robot)?
    a How much have you experienced it so far?
    b What is it like?
    c What are you excited about?
    d What are you not so excited about?
    e Does this make you wonder about the future of school?

## II. POST-INTERVENTION PROTOCOLS AND QUESTION ORDER

C. RT student interview:

1. Tell us one thing about your experience.
2. What were some of the group projects you were able to participate in?
3. What surprised you about using the robot?
4. What was it like after some time?
5. What worked really well?
6. What things may have been more challenging?
7. What are some of your thoughts being physically vs. robotically present?
8. What was better / worse / same?
9. Did it seem like you were part of the class?
10. What about friends?
11. Did you ever take the robot out of the classroom?
12. Do many students stare at you at assemblies?
13. Did it make you feel special (unique)?
14. What would make it better?
15. Future of robotics in schools?
16. Could you envision more students connecting like you did?
17. Would you like a friend also connecting by robot?
18. Was there anything that was frustrating about the robots?
19. Anything that you would like us to know?
20. If you were going to write a book for other students?
21. Anything regarding the experience they should be ready?
22. What did your parents think?
23. Do you have any other thoughts?

## II. POST-INTERVENTION PROTOCOLS AND QUESTION ORDER (continued)

C. Student focus groups

1. What are your thoughts about robotics in the classroom?
2. Did your opinion change over time?
3. What were some of the good things?
4. What were some surprising things that you didn't expect?
5. What were some of the challenges?
6. What activities worked well?
7. How did this change the way you experienced class?
8. Did it seem like she was part of the class?
9. What would you differently?
10. How is this different than video conferencing?
11. Anything else we should know?
12. Future implications?

D. Teacher Interview

1. What has been good about robotic telepresence?
2. Anything surprising to you?
3. Any specific activities challenging?
4. Change over time?
5. If you were to author a book about this, what would you want others to know?
6. Would you add more robots in future classes?
7. Do you have any other thoughts?